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DEFENSE AGAINST BALLISTIC MISSILES

An Assessment of Technologies and Policy Implications

DEFENSE AGAINST BALLISTIC MISSILES

An Assessment of Technologies and Policy Implications

Department of Defense

April 1984

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Washington, D.C. 20402

THE SECRETARY OF DEFENSE

WASHINGTON, THE DISTRICT OF COLUMBIA

Since the dawn of the nuclear age, the United States has sought to preserve peace through deterrence. By making the cost of aggression far greater than any potential gain, the United States has successfully deterred conflict between the major powers for almost four decades.

In the face of an expanding Soviet nuclear arsenal, this Administration has taken steps to strengthen the offensive arm of deterrence while also working for significant, verifiable arms reductions. But President Reagan has also offered the hope of a world made even safer from the threat of nuclear conflict if we could develop defensive systems.

America has always drawn on its technological genius to strengthen its deterrent--both strategic and conventional. And now recent advances in technology offer us, for the first time in history, the opportunity to develop an effective defense against ballistic missiles and the possibility of fulfilling President Reagan's vision of a safer world. Achieving that worthwhile goal will not be easy. For that reason, the analysis provided by the Defensive Technologies Team and the Future Security Team is indispensable.

To carry on the work that those study teams began, the Department of Defense has combined into a single Strategic Defense Initiative previously planned research and development programs in five technology areas. Those areas that offer the greatest promise for an effective defense against ballistic missiles are: surveillance, acquisition, and tracking; directed energy weapons; kinetic-energy weapons; systems analysis and battle management; and support programs, such as space electrical power and heavy lift launch vehicles. To the $1.74 billion already planned for research in those five technological areas, the Defense Department has requested an additional $250 million to begin testing weapons lethality, to research spacecraft survivability, and to exploit other new technological opportunities.

Successful completion of our research programs to determine the most effective defense against ballistic missiles will require the cooperation of many different organizations and all the Military Services. To coordinate all those efforts, the President has directed that we establish a centralized management office within the Department of Defense. The Program Manager will report directly to the Secretary of Defense and will hold frequent reviews to assess progress and make decisions concerning future direction of the Strategic Defense Initiative.

We firmly believe that our research can point out ways to achieve a reliable and effective ballistic missile defense that will enhance deterrence for the United States and our allies. But to succeed in that vital endeavor, we must have the full support of Congress and the American people and wholehearted participation by America's scientists and strategists.

While much remains to be done, we have made a good beginning with these two fine studies. It is vitally important that we continue our efforts to put an end to the threat of nuclear weapons. There can be no winners in a nuclear war. That terrible truth provides the incentive; science provides the opportunity. For the benefit of all mankind, we are committed to seizing that opportunity without delay.

Caspar W. Weinberger

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PREFACE

In March 1983, President Reagan offered a hopeful vision of the future based on a program to "counter the awesome Soviet missile threat with measures that are defensive." He said, "we must thoroughly examine every opportunity for reducing tensions and for introducing stability into the strategic calculus of both sides." He spoke of the massive and continuing Soviet buildup of nuclear and nonnuclear forces and of the bleakness of the future before us if we rely solely on the threat of retaliation to deter Soviet attacks against the United States or our allies. The President proposed a strategy that would "significantly reduce any incentive that the Soviet Union may have to threaten attack." He asked, "what if free people could live secure in the knowledge that . . . we could intercept and destroy strategic ballistic missiles before they reached our own soil or that of our allies?"

The President ordered an assessment of technologies and systems that might provide a defense against ballistic missiles, together with a study of the policy implications of ballistic missile defenses for the United States and our allies. From June through October 1983, these two studies were conducted in close coordination,* and this report is based on them.

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*The study of technologies and systems for ballistic missile defense was conducted by a team of scientists under the direction of Dr. James C. Fletcher. The implications for defense policy, strategy, and arms control were addressed by two study teams: an interagency team of experts led by Mr. Franklin C. Miller and a team of outside experts led by Mr. Fred S. Hoffman.

POLICY IMPLICATIONS OF DEFENSES AGAINST BALLISTIC MISSILES

During the 1950s, the United States maintained substantial programs for defense against possible attack by Soviet bombers. But in the 1960s, in light of the growing threat from Soviet missiles, the United States Government concluded that an effective missile defense would be most difficult to achieve. Moreover, it was thought that deployment would not be desirable because it might provide an incentive for the Soviets to further increase their offensive strategic forces to overwhelm our missile defenses, and that they could do so at a cost much lower than our cost for missile defenses. And once our increasing vulnerability to Soviet missile attacks was accepted, it did not seem warranted to continue a major effort for defense against Soviet bombers. As a result, we largely disbanded our air defenses in the 1960s.

At the same time, a strategic theory gained currency in the United States that held that deterrence of nuclear attack could best be maintained if both the United States and the Soviet Union were vulnerable to attack. This theory found expression in the Anti-Ballistic Missile (ABM) Treaty, which was designed to foreclose widespread deployment of ballistic missile defenses, and in the anticipation that we could reach agreements first to limit and then to reduce strategic offensive forces.

Unfortunately, neither the U.S. abandonment of the attempt to defend against nuclear attack in the 1960s nor the ABM Treaty and the Strategic Arms Limitation Talks (SALT I and II) agreements have led to a leveling off in the growth of offensive systems—much less to reductions. Moreover, unlike the United States, the Soviet Union has continued to maintain and modernize both a large nationwide air defense system and ballistic missile defenses around its capital (as permitted by the ABM Treaty). In addition, as the President recently reported to the Congress, the Soviet Union has now deployed a large radar in central Siberia that almost certainly constitutes a violation of

legal obligations under the ABM Treaty since its associated siting, orientation, and capability are prohibited by this Treaty. The Soviets have also been conducting research in technologies that would be required for more effective missile defenses.

The continual growing Soviet offensive threat to the United States and our allies plus the ongoing Soviet research and deployment of defensive systems offers a powerful motive for reassessing the potential role of defensive systems in our security strategy. At the same time, advances in relevant technologies require us to reassess the feasibility of useful defenses. The conjunction of these issues prompted the President to call for a new assessment of the possibilities for increasing the role of defensive systems in our deterrent posture.

It is to be expected that the technological approaches proposed would vary widely in technical risk and strategic uncertainty. For the first time in history, we have the possibility of developing a multitiered system. Such a system could defend against enemy ballistic missiles in all phases of their flight, not only in the terminal phase, where decoys and multiple reentry vehicles (MIRVs) constitute a large number of objects that the defense must cope with. The current technology addresses only the final reentry phase. A capability to intercept missiles in the boost and post-boost phases could defend against a missile attack before the deployment of a multiplicity of reentry vehicles and decoys.

We do not yet have enough information for estimating the entire cost of a full research and development program for a multitiered missile defense. The costs of actual development of various possible systems will, of course, depend on the characteristics of the systems. Clearly, costs of defenses and the trade-offs with offensive forces they will permit and require are among the most critical issues. The costs will, however, be spread over many years, and decisions on the desired magnitude of the effort can—and should—be taken at various stages in the program. At this time, one cannot prejudge the extent to which costs of increasingly more effective defense deployments will be warranted by the resultant security benefits and defense savings in other areas.

The role of ballistic missile defenses must be viewed in the context of the overall military and political requirements of the United States.

A decision to pursue ballistic missile defenses would have major implications for nuclear strategy, the prevention of nuclear war, deterrence of aggression, and arms reduction. It is with this broad context in mind that our policy on missile defenses must be shaped. To permit informed decisions we have to conduct research on many aspects of the relevant technology and develop a range of specific choices.

It is likely that components of a multilayered defense, or less than fully effective versions of such a defense, could become deployed earlier than a complete system. Such intermediate versions of a ballistic missile defense system, while unable to provide the protection available from a multitiered system, may nevertheless offer useful capabilities. The development of options to deploy such intermediate capabilities would be an important hedge against an acceleration in the Soviet strategic buildup. If such intermediate systems were actually deployed, they could play a useful role in defeating limited nuclear attacks and in enhancing deterrence against large attacks.

Intermediate defense capabilities would reduce the confidence of Soviet planners in their ability to destroy the high-priority military targets that would probably be the primary objective of a contemplated Soviet attack. The planners' decreased confidence in a successful outcome of their attacks against military targets, war-supporting resources within the United States, or U.S. and allied forces overseas would strengthen deterrence of Soviet use of nuclear arms.

An effective, fully deployed U.S. ballistic missile defense could significantly reduce the military utility of Soviet preemptive attacks, thereby potentially increasing both deterrence and strategic stability. But such a defense could remain effective only if the Soviet Union could not negate it with countermeasures more cheaply than the United States could maintain the viability of the system or if the two sides agreed to limit offensive missile forces while protecting defensive systems. Effective defenses strengthen deterrence by increasing an attacker's uncertainty and undermining his confidence in his ability to achieve a predictable, successful outcome. By constraining or eliminating the effectiveness of both limited and major attack options against key U.S. military targets and thus leaving only options for attacking urban areas—which would be of highly

questionable credibility—defenses could significantly reduce the utility of strategic and theater nuclear forces and raise the threshold of nuclear conflict.

It must be recognized, however, that there are uncertainties that will not be resolved until more is known about the technical characteristics of defensive systems, the future arms policies of the Soviet Union, the prospects for arms reduction agreements, and the Soviet response to U.S. initiatives. Important questions to be addressed are

- the absolute and relative effectiveness of future U.S. and Soviet defensive systems and how this effectiveness is perceived by each side;
- the vulnerabilities of the defensive systems (both real and perceived);
- the size, composition, and vulnerabilities of each side's offensive forces;
- the overall U.S.-Soviet military balance.

While these uncertainties cannot be fully resolved, we will learn more about them with the passage of time. Our assessment of these issues will affect design and deployment decisions.

These uncertainties notwithstanding, a vigorous R&D program is essential to assess and provide options for future ballistic missile defenses. At a minimum, such a program is necessary to ensure that the United States will not be faced in the future with a one-sided Soviet deployment of highly effective ballistic missile defenses to which the only U.S. answer would be a further expansion of our offensive forces ("penetration aids," more launchers, etc.). Such a situation would be fraught with extremely grave consequences for our security and that of our allies. There is no basis for the assumption that decisions on the deployment of defensive systems rest solely with the United States. On the contrary, Soviet history, doctrine, and programs (including an active program to modernize the existing Moscow defense—the only operational ballistic missile defense in existence) all indicate that the Soviets are more likely (and better prepared) than we to initiate such a deployment whenever they deem it to their advantage. For the near future, in particular, they are better prepared than we to deploy traditional ("conventional") terminal defenses. U.S. work on ballistic missile defense technology in the 1960s and early 1970s appears to have been an important factor in

Soviet willingness to agree to the deployment limits imposed by the ABM Treaty; similar considerations can be expected to play a role in future Soviet decisions on the deployment of ballistic missile defenses.

If U. S. research efforts on defensive technologies prove successful, and are so perceived by the Soviet Union, such technologies could fundamentally alter the nature of the strategic relationship between the United States and the Soviet Union. Advanced ballistic missile defenses have the potential for reducing the military value of ballistic missiles and lessening the importance of their role in the strategic balance. In reducing the value of these weapons, defensive technologies could substantially increase Soviet incentives to reach agreements reducing nuclear arms. In conjunction with air defense and effective, agreed constraints on all types of offensive nuclear forces, highly effective ballistic missile defenses could drastically diminish the threat of massive nuclear destruction.

Nevertheless, the immediate response of the Soviet Union to a U.S. effort to develop ballistic missile defenses is likely to be a continuation of its current political and diplomatic campaign to discredit such defenses. At the same time, the Soviet Union will continue its own efforts on air defenses and on both existing and advanced ballistic missile defenses. The Soviets can also be expected to press ahead with further expansion and modernization of their offensive systems. The Soviets may change their pattern of behavior if they become convinced that the American commitment to the deployment of defenses is serious, that there are good prospects for eventual success in the development of ballistic missile defenses, and that such deployments present opportunities for a safer U.S.-Soviet nuclear relationship.

Since long-term Soviet behavior cannot reliably be predicted, we must be prepared to respond flexibly. A research and development program on ballistic missile defense that provides a variety of deployment options will help resolve the many uncertainties we now confront and over time offers the United States flexibility to respond to new opportunities. By contrast, without the research and development program, we condemn future U.S. Presidents and Congresses to remain locked into the present exclusive emphasis on deterrence through offensive systems alone.

If, for example, the Soviets persisted in attempts to expand their massive offensive forces, a flexible research and development program would force Soviet planners to adopt countermeasures, increasing the costs of their offensive buildup and reducing their flexibility in designing new forces in a manner that they would prefer. Over time, our research and development on ballistic missile defense might induce a shift in Soviet emphasis from ballistic missiles, with the problems they pose for stability, in favor of air-breathing forces with slower flight times. By constraining Soviet efforts to maintain offensive forces and making them more costly, U.S. options to deploy ballistic missile defenses might increase our leverage in inducing the Soviets to agree to mutual reductions in offensive nuclear forces. In turn, such reductions could reinforce the potential of defensive systems to stabilize deterrence. Reductions of the magnitude proposed by the United States in the Strategic Arms Reduction Talks (START) would be very effective in this regard.

In its initial stages, a U.S. ballistic missile defense research and development program would be consistent with existing U.S. treaty obligations. Were we to decide on deployment of a widespread defense of the United States, the ABM Treaty would have to be revised. If the results of the research and development program warranted such a decision in the future, it would be appropriate to address it in the context of a joint consideration of offensive and defensive systems. This was the context contemplated at the outset of the SALT negotiations; but while we reached an agreement limiting defenses, our anticipations of associated limitations on offensive forces have not yet been realized.

Both the Soviet national interest and traditional themes in Soviet strategic thought give reason to expect that the Soviets will respond with increased dependence on defensive forces relative to offensive forces. The nature of a cooperative transition to defensive forces would depend on many factors, including the technical aspects of each side's defensive systems, their degree of similarity or dissimilarity, and whether U.S. and Soviet systems would be ready for deployment in the same period. Because of the uncertainties associated with these factors, no detailed blueprint for arms control in the transition period can be drawn at this time. A list of arms control measures might include agreed schedules for introducing the defensive systems of both sides, and associated schedules for reductions in ballistic missiles and other nuclear forces. Confidence-building measures and

controls on devices designed specifically to attack or degrade the other side's defensive systems are other potential arms control provisions.

If both the United States and the Soviet Union deployed defensive systems against a range of nuclear threats, it would not diminish the need to strengthen U.S. and allied conventional military capabilities. Moreover, to realize the protection offered by a fully effective strategic defense, we would require air defenses so that the ballistic missile defense could not be circumvented by increased deployments of bombers and cruise missiles. The integration of defenses against air-breathing vehicles with defenses against ballistic missiles requires further study.

Defense against ballistic missiles offers new possibilities for enhanced deterrence of deliberate attack, greater safety against accidental use of nuclear weapons or unintended nuclear escalation, and new opportunities and scope for arms control. The extent to which these possibilities can be realized will depend on how our present uncertainties about technical feasibility, costs, and Soviet response are resolved. Clearly, the pursuit of defensive systems should not build only on our present policies of maintaining peace; it should also seek to strengthen the effectiveness of our strategic policy in the face of a growing Soviet threat. The essential objective of the U.S. strategic defense initiative is to diminish the risk of nuclear destruction—contrasted with continued, sole reliance on the threat of nuclear retaliation—to provide for a safer, less menacing way of preventing nuclear war in the decades to come.

TECHNOLOGIES FOR DEFENSE AGAINST BALLISTIC MISSILES

Six broad areas were addressed by the technologies study team:

- surveillance of Soviet missile forces and acquisition and tracking of missile attacks;
- directed energy weapons for missile defense;
- more-conventional weapons for missile defense;
- control and coordination of the battle between the offensive missile forces and our defenses, together with its requirements for communications and data processing;

- concepts for an integrated defensive system;
- possible Soviet countermeasures and tactics.

The goal of the study was to provide guidance for research and development programs, in particular for the development of technologies that could make possible a defense against ballistic missiles. As a first step, the research and development program should further informed decisions on subsequent engineering programs seeking to test the technologies.

In addition, the study identified demonstrations of key components of a missile defense that could be conducted by the end of this decade. These demonstrations can provide a basis for choosing specific, partial missile defense systems to be deployed by the early 1990s. Such partial systems could defend perhaps a few critical targets, especially against smaller attacks. In the event of a large missile attack, however, many missiles would reach their targets. Yet even the limited effectiveness of a partial system could make a significant contribution to deterrence by depriving the enemy planner of reliable military results of his attack.

This study dealt only with defenses against ballistic missiles; defenses against bombers and cruise missiles have been evaluated in other studies.

The principal conclusions of this study were that

- new technologies for ballistic missile defense hold promise that warrants a major research and development effort to provide specific options for defensive systems;
- through demonstration projects, evidence and measurement of progress on the required technical capabilities can be provided within the next ten years;
- development of all the technologies essential for a comprehensive ballistic missile defense will require effective coordination through central management for the research and development efforts;
- the most effective defensive systems have multiple layers, or tiers;
- a combination of technologies and special tactics needs to be developed to protect vulnerable components of the future defense system.

A. The Ballistic Missile Attack

Advances in Soviet and U.S. technology warrant a reevaluation of ballistic missile defenses. Over the past twenty years, the Soviet threat from ballistic missiles has increased steadily. For purposes of analysis, this study assessed a variety of potential future threats, ranging from an attack with fewer than 100 ballistic missiles and a few hundred warheads to an attack with thousands of missiles launched simultaneously with tens of thousands of warheads. The study focused on the most demanding case—a ballistic missile attack, unconstrained by arms limitations, that would impose the greatest stress on a defensive system.

In seeking to determine the best defense, the study team analyzed the characteristics of a ballistic missile throughout all four phases of a typical trajectory (Figure 1). In the boost phase, the first- and second-stage engines of the missile are burning, producing intense infrared radiation that is unique. A post-boost, or bus deployment, phase occurs next, during which multiple warheads and enemy "penetration aids" are released from a missile. (Penetration aids are objects that accompany a missile attack, designed to saturate defenses.) Next, in the midcourse phase, warheads and penetration aids travel on ballistic trajectories above the atmosphere. In the final phase, the warheads and penetration aids reenter the atmosphere, where they are affected by atmospheric drag.

B. Characteristics of an Effective Defense Against Ballistic Missiles

1. Defense in Depth. For many years now, ballistic missile defense studies and experiments have continued to support the conclusion that an efficient defense against large missile attacks would need to be multitiered. Some missiles (or other objects that are part of the attack) will be able to penetrate any one defensive tier; those that have not been intercepted at one phase will move on to the next phase. For example, a 10 percent "leakage" in each of three tiers would amount to an overall leakage of only 0.1 percent. A single layer that can achieve 90 percent effectiveness is many times less costly than a single layer of 99.9 percent effectiveness. It is thus reasonable to construct a three- or four-layer defense with 99.9 percent effectiveness at far less

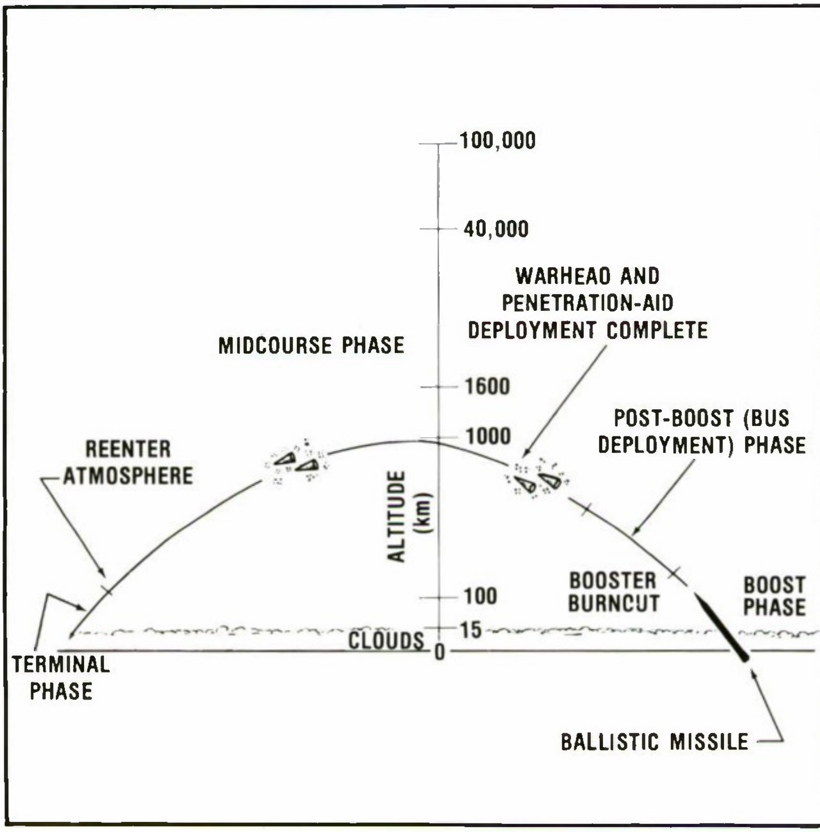

Figure 1. Phases of a typical ballistic missile trajectory. During the boost phase, the rocket engines accelerate the missile payload through and out of the atmosphere and provide intense, highly specific observables. A post-boost, or bus deployment, phase occurs next, during which multiple warheads and penetration aids are released from a post-boost vehicle. In the midcourse phase, the warheads and penetration aids travel on trajectories above the atmosphere, and they reenter it in the terminal phase, where they are affected by atmospheric drag.

cost than that of the equivalent single-layer defense. Finally, a multi-tiered defense complicates an attacker's planning because any single method an attacker used to circumvent the defensive system would not be equally effective for each tier. This compounds the uncertainty of Soviet planners about the effectiveness of a missile attack that they might contemplate.

2. Defense at Each Tier. The effective reach of a terminal-defense interceptor is determined by how fast it can fly and how early it can be launched. Terminal-defense interceptors fly within the atmosphere. The precise timing of their launching is linked to discrimination of their real targets from penetration aids and accompanying debris. Terminal defense must be complemented by area defenses that intercept incoming warheads at long ranges. Intercepts outside the atmosphere, designed to eliminate threatening warheads while they are still in the midcourse trajectory, offer such a complement. Figure 2 illustrates one of many possible concepts for terminal-phase intercept. New technologies make it possible to perform these intercepts with nonnuclear warheads.

Midcourse intercept requires the defense to identify decoys designed precisely to attract interceptors and exhaust the defending force prematurely. Fortunately, in this phase, there is more time available than at later stages to engage objects in trajectory. The midcourse defensive system must provide both early filtering, or discrimination, of nonthreatening objects and continuing warhead attrition to minimize the demand placed on the terminal system. Placing a layer of defense intercept *before* midcourse is an attractive option. To delay the start of the defensive effort *until* midcourse would accept the risk of a large increase in the number of objects the defense must cope with because multiple independently targeted reentry decoys would have been deployed. Figure 3 illustrates one of many possible concepts for midcourse-phase intercept.

In the post-boost phase, the defense must cope with an increasing number of objects in the enemy attack, as decoys and reentry vehicles are deployed. On the other hand, the post-boost phase offers additional time for interception and an opportunity to discriminate between warheads and deception objects as they are deployed. Figure 4 illustrates one of many possible concepts for boost-phase and post-boost-phase intercept.

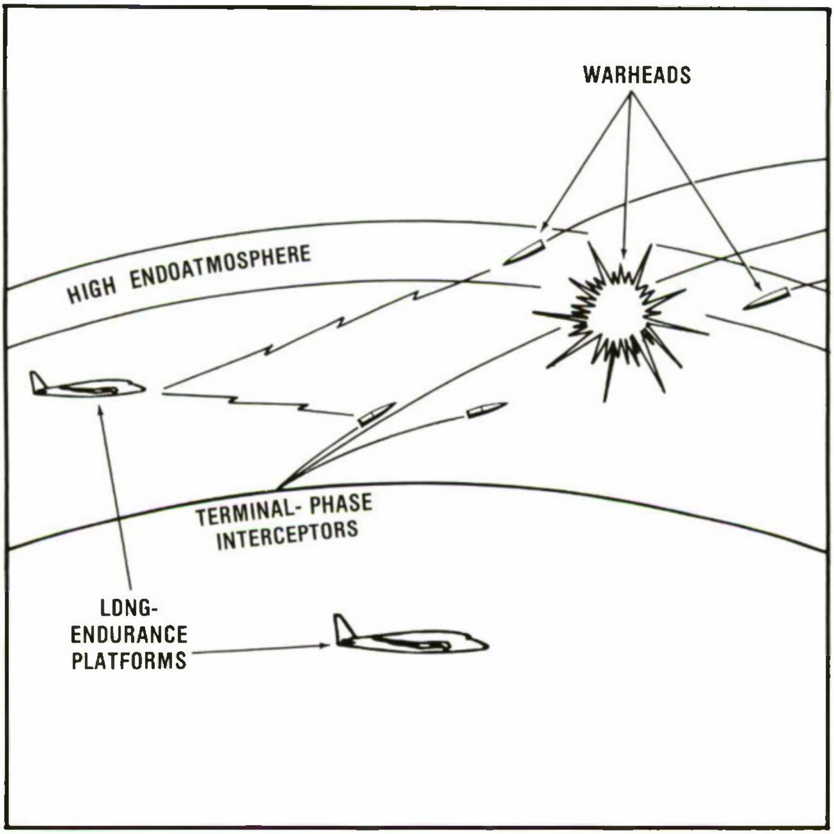

Figure 2. Strawman concept for ballistic missile defense during the terminal phase. This phase is the final line of defense. Threatening objects include warheads shot at but not destroyed, objects never detected, and decoys neither discriminated nor destroyed. These objects must be dealt with by terminal-phase interceptors. An airborne optical adjunct is shown here. Reentry vehicles are detected in late exoatmospheric flight with sensors on these long-endurance platforms. The interceptors—nonnuclear, direct-impact projectiles—are guided to the warheads that survived the engagements in previous phases.

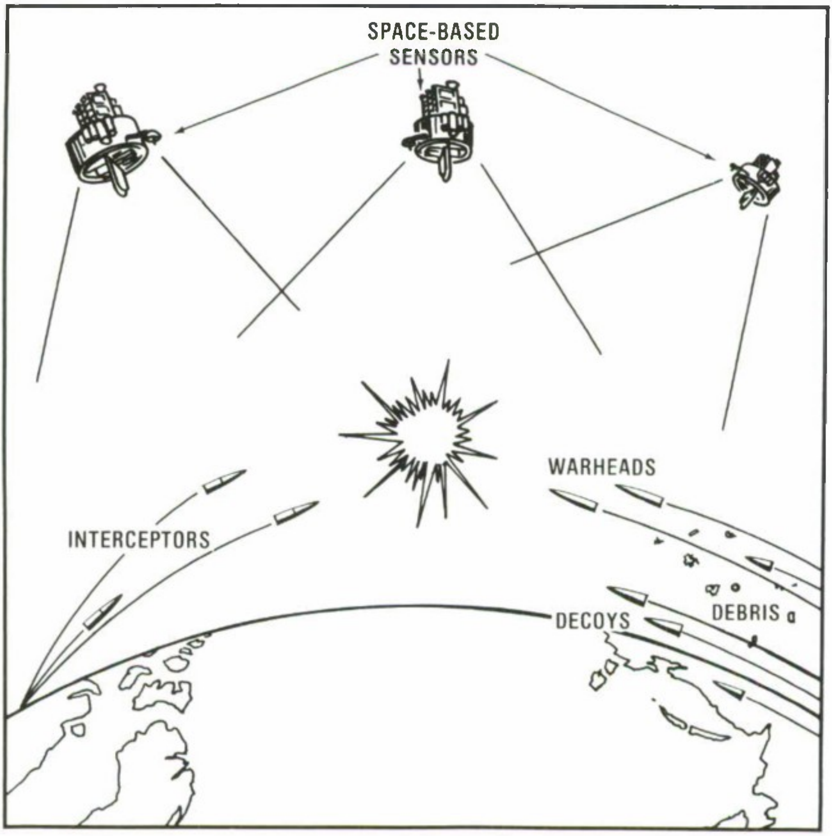

Figure 3. Strawman concept for ballistic missile defense during the midcourse phase. Intercept outside the atmosphere during the midcourse phase requires the defense to cope with decoys designed to attract interceptors and exhaust the defending force. Continuing discrimination of nonthreatening objects and continuing attrition of reentry vehicles will reduce the pressure on the terminal-phase system. Engagement times are longer here than in other phases. The figure shows space-based sensors that discriminate among the warheads, decoys, and debris and the interceptors that the defense has committed. The nonnuclear, direct-impact projectiles speed toward warheads that the sensors have identified.

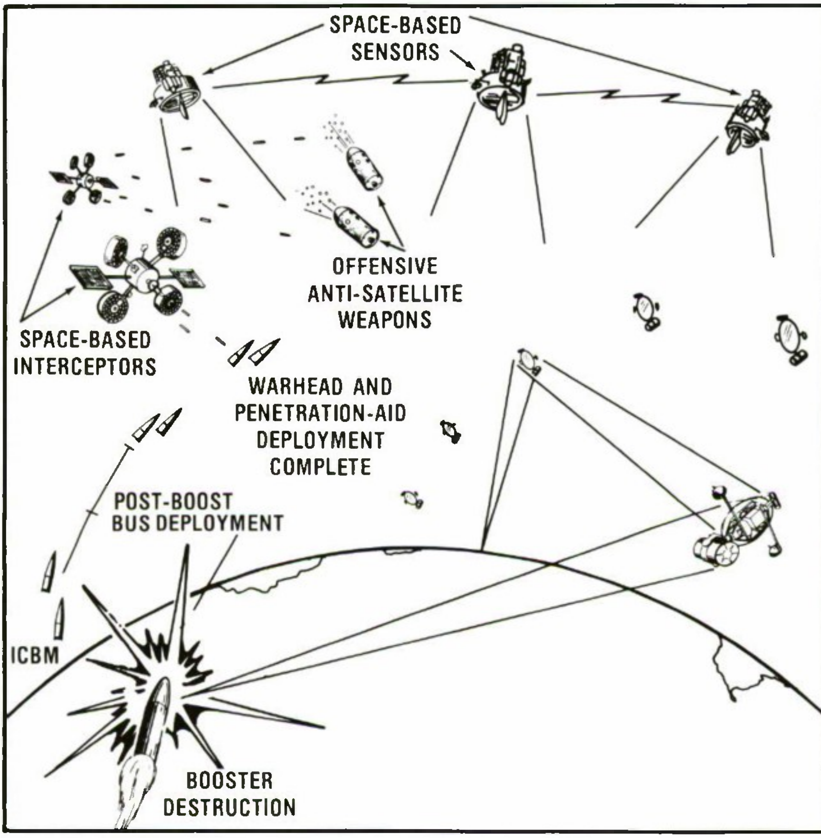

Figure 4. Strawman concept for ballistic missile defense during the boost phase. An essential requirement is a global, full-time surveillance capability to detect an attack and define its destination and intensity, determine targeted areas, and provide data to guide boost-phase intercept and post-boost vehicle tracking systems. Attacks may range from a few missiles to a massive, simultaneous launch. For every booster destroyed, the number of objects to be identified and sorted out by the remaining elements of a multitiered defense system will be reduced significantly. An early defensive response will minimize the numbers of deployed penetration aids. The transition (post-boost phase) from boost phase to midcourse allows additional time for intercept by boost-phase weapons and for discrimination between warheads and deception objects. Space-based sensors detect and define the attack. Space-based interceptors protect the sensors from offensive anti-satellite weapons and, as a secondary mission, attack the missiles. In this depiction nonnuclear, direct-impact projectiles are used against the offensive weapons.

Consequently, an ability to defend effectively against large Soviet missile attacks would be strongly dependent on the effectiveness of a boost-phase intercept system. For every booster destroyed, the number of objects to be identified and sorted out by the remaining elements of a layered ballistic missile defense system is reduced sharply. Because each booster is capable of deploying tens of reentry vehicles and hundreds of decoys, the defense, by destroying the boosters, has to destroy 1 percent or fewer of the objects it would have to cope with in subsequent phases of the missile trajectory—truly substantial leverage. Yet a boost-phase system is itself constrained by the very short time during which the target can be engaged and the potentially large number of targets. Because of these constraints, and because of the need to obtain the maximum leverage from all tiers of the strategic defensive system, we need an effective system for surveillance and for commanding and allocating the defenses against a missile attack ("battle management").

Each phase in the layered defensive system presents different technical challenges. But in each phase, a defensive system must perform three basic functions: first, surveillance, acquisition, and tracking; second, intercept and target destruction; and third, battle management.

C. Key Functions of a Ballistic Missile Defense

A ballistic missile defense capable of engaging the missile attack all along its flight path must perform certain functions:

- *Promptly and reliably warn of an attack and initiate the defense.* Global, full-time surveillance of ballistic missile launch areas is required to detect an attack, define its destination and intensity, and provide data to guide boost-phase intercept and post-boost tracking systems.
- *Continuously track all threatening objects from the beginning to the end of their trajectories.* This objective would allow accurate and timely data transfer from tracking systems to intercept systems, permitting the assignment of intercepts to attacking reentry vehicles.
- *Efficiently intercept and destroy the booster or post-boost vehicle.* The defense must be capable of dealing with attacks ranging from a few dozen missiles to a massive, simultaneous launch. An early attack on post-boost vehicles will minimize the number of penetration aids deployed.

- *Efficiently discriminate between enemy warheads and decoys through filtering of lightweight penetration aids.* The system must be capable of rapidly and effectively discriminating decoys or penetration aids from reentry vehicles (warheads). The more effective such discrimination, the greater the cost to the offense in providing the necessary mass and volume for decoys that cannot be filtered out.
- *Low-cost intercept and destruction in midcourse.* Accurate recognition of the enemy warheads (reentry vehicles) in this phase and a capability to intercept them cheaply will increase the enemy's difficulty and cost in mounting an effective attack. To discourage the Soviet Union from increasing the number of warheads, the cost to the U.S. defense for interceptors should be less than the cost to the Soviet offense for warheads.
- *Terminal intercept at the outer reaches of the atmosphere and destruction.* The final phase involves the relatively short-range intercept of each reentering warhead.
- *Battle management, communications, and data processing.* These are the connecting elements that coordinate all system components to gain effectiveness and economy of force.

D. The Effect of Advances in Defense Technologies

Because of recent advances in technology, it is now possible to specify how these key functions of an effective ballistic missile defense could be met. For example, two decades ago no reliable means for boost-phase intercept were known. Now, several approaches are becoming feasible for boost-phase defenses, based on directed energy concepts (such as particle beams and lasers) and methods for destroying enemy missiles based on kinetic energy (including nonnuclear rocket-propelled projectiles and hypervelocity guns).

Twenty years ago, midcourse intercept was difficult. No credible concepts for decoy discrimination existed, the intercept cost was high, and the unintended damage caused by nuclear weapons then necessary for the interceptor warheads was unacceptable. Today, multispectral sensing of incoming objects with laser imaging and millimeter-wave radar, tracking through all phases of the trajectory, and inexpensive direct-impact projectiles give promise of overcoming the difficulties of midcourse intercept.

A few years ago, it was not yet possible to design a method to differentiate between penetration aids and warheads at high altitudes. This shortcoming, combined with limited interceptor performance, meant that an effective defense would have required too many interceptors. Now, technological advances provide new ways to discriminate among multiple incoming objects, as well as to intercept missiles at high altitudes. Coupled with an ability to intercept enemy missiles and warheads in boost phase and midcourse and to disrupt coordinated enemy attacks, these improvements would greatly increase the effectiveness of terminal defenses.

But it is not sufficient to develop the capability to destroy incoming targets without also developing the capability to manage the allocation of interceptors and their integration with other portions of a multitiered defense system. Computer hardware and software and signal processing in the 1960s was incapable of supporting such a multitiered defense battle management. Today, technological advances permit the development of effective command, control, and communications facilities.

New technology also offers more effective solutions to the problem of discriminating between a warhead and a decoy or debris. By using both active and passive sensors, a ballistic missile can be observed during its trajectory to determine the presence of a warhead. An active sensor determines the location and motion of the object by measuring radiation that has been directed from the sensor to the object and reflected from the object back to the sensor; a passive sensor relies on radiation emanating from the object. Active techniques, such as creating an observable thermal response by an object to a continuous-wave laser, and passive techniques, such as observing with infrared sensors, are possible ways to improve surveillance, acquisition, and tracking of missiles. Both active and passive surveillance techniques are being developed to image an object in order to determine by its appearance what it is. It is important to understand that any one sensor can be defeated, but it is far more difficult to defeat several operating simultaneously.

E. The New Technologies

1. Surveillance, Acquisition, and Tracking. As each potential reentry vehicle begins ballistic midcourse flight accompanied by

deployment hardware (or "space junk") and possibly by decoys, every object must be evaluated and accounted for from the beginning to the end of the trajectory, even if the price is many wasted evaluations about what are, in effect, decoys. Defending interceptor vehicles must also be tracked to maintain a complete and accurate status of the engagement.

Midcourse sensors must be able to discriminate between warheads that survive through the post-boost deployment phase and non-threatening objects such as decoys and debris. They must also provide warhead position and trajectory data to permit timely and accurate employment of interceptors and to assess target destruction. The minimum requirements are to track all objects designated as reentry vehicles and also to track other objects that might be confusing in later tiers.

Space-based, passive infrared sensors could provide the means to meet these tracking requirements. They could permit long-range detection of warheads (or cold objects) against the space background and the elimination of simple, lightweight objects, leading to determination of the full trajectories of threatening objects. Laser trackers could also provide validation to determine if targets had been destroyed, as well as precision tracking of objects as they continue through midcourse. As the objects proceeded along their trajectories, data would be handed off from sensor to sensor and the computerized tracking files progressively improved.

For the final line of the defense, the surveillance and tracking would be based, where possible, on the data collected from the midcourse engagement. This task would consist of sorting all objects that have leaked through the early defense layers to identify the remaining enemy reentry vehicles. Objects to be tracked would include reentry vehicles shot at but not destroyed, reentry vehicles hitherto undetected, and decoys and other objects that were neither identified nor destroyed. These possible threatening objects must be assigned to final-phase interceptors.

One innovative concept for that phase involves an airborne optical adjunct—a platform put into position on warning of attack—that would help detect arriving reentry vehicles using infrared sensors (much as space-based sensors had done in midcourse), tracking those not previously selected. Airborne sensors could also provide data

necessary for additional discrimination. They could acquire and track objects as they were about to reenter the atmosphere and observe interactions of those objects with the atmosphere from the beginning of reentry. At that point, a laser or radar would precisely measure the position of each object and refine its track before interceptors would be committed.

2. Intercept and Destruction of Threatening Objects. A variety of mechanisms, including directed energy, can destroy an object at any point along its trajectory. The study identified several promising possibilities. A laser relying on advanced technology can be designed to produce a single giant pulse that delivers a shock wave to a target. The shock causes structural collapse. A continuous-wave or repetitively pulsed laser delivers radiant thermal energy to the target. Contact is maintained until a hole is burned through the target or the temperature of the entire target is raised to a damaging level. Examples of such lasers are free-electron lasers, chemical lasers (hydrogen fluoride or deuterium fluoride), and repetitively pulsed excimer lasers.

There are other possible means of destroying incoming warheads. A neutral-particle beam could deposit sufficient energy within a missile or warhead to destroy its internal components. In conventional warfare, guns and missiles destroy their targets through kinetic-energy impact supplemented with a chemical explosive in some cases. In defending against ballistic missiles, homing projectiles propelled by chemical rockets or by hypervelocity guns, such as the electromagnetic gun based on the idea of an open solenoid, could destroy warheads in all phases.

3. Battle Management. The tasks of battle management are to

- monitor the global situation,
- allocate all available defense weapons (interceptors, etc.),
- determine their best use,
- report results.

A layered battle-management system would correspond to the different layers of the ballistic missile defense system, each layer being semiautonomous, with its own processing resources, rules of engagement, sensor inputs, and weapons. During an engagement, data would be passed from one phase to the next. The exact system architecture

would be highly dependent on the mix of sensors and weapons, and the geographical scope of the defense to be managed would determine the structure of the battle-management system.

As sensors survey the field of battle, raw data are filtered to reduce the volume. Later processes organize these data according to (1) the size of the object, (2) orbital parameters and positions as a function of time, and (3) listings of other data that help identify and assess the threat inherent in the object that is being tracked. In principle, all objects in the field of view of the sensors are candidates for tracking, and all objects that cannot readily be rejected as nonthreatening would appear in the file—the representation of the total battle situation.

Defense system resources include sensors and weapons, the data-processing and communication equipment, and the platforms (or "stations") on which these and other components are emplaced. The assignment of these resources—both sensor and weapon—is a dynamic process requiring reexamination throughout an engagement. For example, sensors must be assigned to sectors or to targets of interest at appropriate times to acquire necessary targeting and tracking data. Weapons must then be assigned to targets as determined by rules of engagement. Defensive resources must extrapolate the present situation into the future to determine the most likely development of the attack and to select a course of action that maximizes the effectiveness of the defense.

F. Meeting the Challenge

The Technologies Study concentrated on the most difficult aspects of a multitiered, four-phase ballistic missile defense system capable of defending against a massive threat—the technologies that pose the greatest challenge. The study team was primarily concerned with technologies whose feasibility would determine whether an effective defense is indeed possible.

1. Critical Technologies. Several critical technologies will probably require research and development programs of ten to twenty years to be ready for deployment as part of such a ballistic missile defense:

- *Boost- and post-boost-phase intercept.* As mentioned earlier, the ability to respond effectively to a very large missile attack is

strongly dependent on countering it during the boost or post-boost phases.

- *Discrimination.* Dense concentrations of reentry vehicles, decoys, and debris must be identified and sorted out during the midcourse and high reentry phase.
- *Survivability.* A combination of tactics and mechanisms to ensure the survival of the system's space-based components must be developed.
- *Interceptors.* By using inexpensive interceptors in the midcourse and early reentry phase, intercept can be sufficiently economical to permit attacks on objects that may not be warheads.
- *Battle Management.* Tools are needed for developing battle-management software.

There is much still to be done. For example, the management of large computer systems will pose important challenges. Developing hardware will not be as difficult as developing appropriate software. Large packages of software (on the order of 10 million lines of code) for reliable, safe, and predictable operation would have to be deployed. Fault-tolerant, high-performance computing would be necessary. Not only must it be maintenance-free for many years, but it must also be radiation-hardened, able to withstand substantial shock, and designed to avoid a sudden failure of the entire computer system. The management of interlocking networks of space-, air-, and ground-based resources would require the development of an accurate means of transferring data between computer systems rapidly and accurately, through system-generated protocols. There must also be a means to reconstitute all or part of the system if portions of it are damaged or made inoperable. In addition, specific ballistic missile defense algorithms will have to be developed for target assignment and a simulation environment for evaluating potential system architectures.

The problem of survivability is particularly serious for space-based components. The most likely threats to the components of a defense system are direct-ascent anti-satellite weapons; ground- or air-based lasers; orbital anti-satellites, both conventional and directed energy weapons; space mines; and fragment clouds. On the ground, traditional methods to enhance survivability can be effective, such as hardening, evasion, proliferation, deception, and active defense. But to protect space-based systems, these methods must be employed in combination. Ideally, the defense system should be designed to

withstand an attack meant to saturate the system. At the very least, the system's most critical points must be protected.

The history of warfare in general and the interactions of weapons technologies in particular indicate that for many potentially successful defenses counters have been developed. It is essential, therefore, to consider possible countermeasures to the development of a ballistic missile defense. But countermeasures are likely to compete with other military programs for available resources and thus may result in diminished offensive capability. For example, hardening of booster rockets of missiles (to withstand a boost-phase missile defense) results in either a reduced payload or a shorter range of the offensive missiles.

2. Logistical Support. The study also described research programs on space logistics that would take five to ten years to complete. In order of priority, the requirements are

(1) development of a heavy-lift launch vehicle for space-based platforms of up to 100 metric tons (220,000 pounds one-time payload);
(2) ability to service the space components;
(3) ability to make available, or to orbit, sufficient materials for space-component shielding against attack;
(4) ability to transfer items from one orbit to another;
(5) multimegawatt power sources for space applications.

Based on the Defensive Technologies Study, the Department of Defense, along with the Department of Energy, has established a new program for the President's Strategic Defense Initiative (SDI). Existing programs relating to the SDI have been focused in five technology areas, and additional funding will be sought to pursue them aggressively. In recognition of its importance, the Strategic Defense Initiative will be centrally managed and will report directly to the Secretary of Defense.

The Strategic Defense Initiative represents one of the most important technological programs the Nation has ever embarked upon—a great hope for the future—but it does *not* represent a deployment attempt, nor is it a substitute for current strategic and conventional force modernization or for arms control. Rather, it will create the technological base for sound deployment decisions. SDI will use America's greatest assets, our creativity and our ingenuity, to lessen the awesome threat of nuclear weapons.